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The intelligent energy system infrastructure for the future

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The intelligent energy system infrastructure for the future

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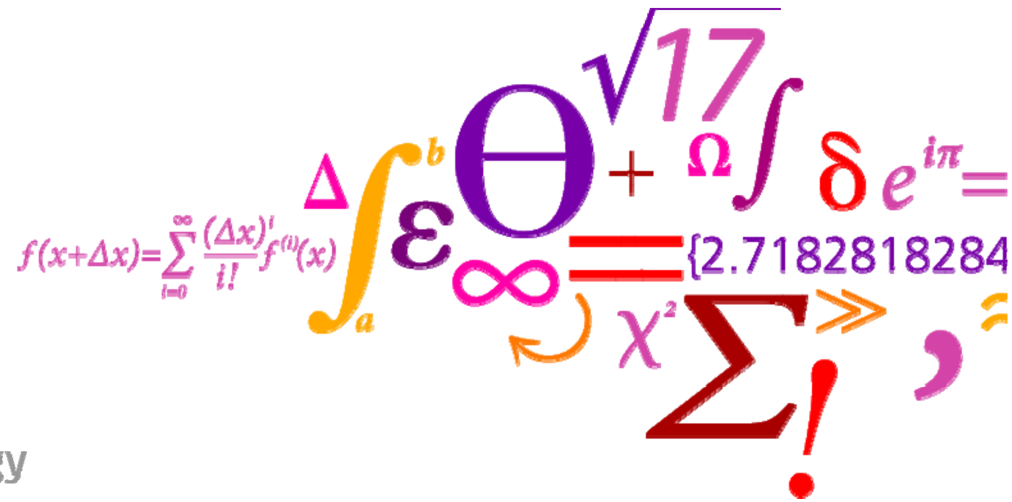


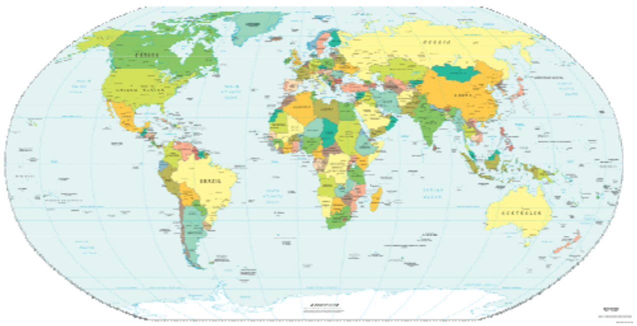
Risø Energy Report 8

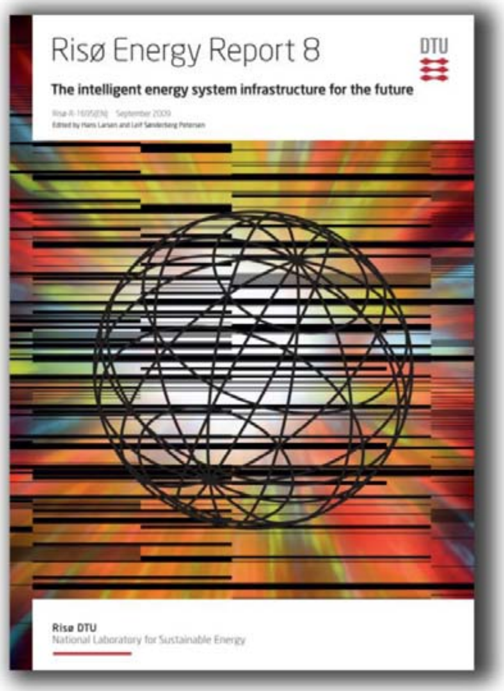
The report is volume 8 in a series that began in 2002

- The report presents the need for the development of a highly flexible and intelligent energy system infrastructure which facilitates substantial higher amounts of renewable energy than today's energy system

- This is necessary to achieve the goals set up by IPCC in 2007 on CO_2 reductions

- The report presents a generic approach for future infrastructure issues on local, regional and global scale with focus on the energy system itself





- Written by researchers from DTU together with other Danish and International experts

- Based on the latest research results together with available international literature

The global energy scene

- Within the energy sector **energy security and climate change** are the two overriding priorities. This is especially true for industrialized countries and the more rapidly developing economies.

- Many developing countries, on the other hand, still face basic energy development constraints which give quite a different meaning to the concept of energy security.

- Today 1.6 billion people have no access to modern energy

The global economy

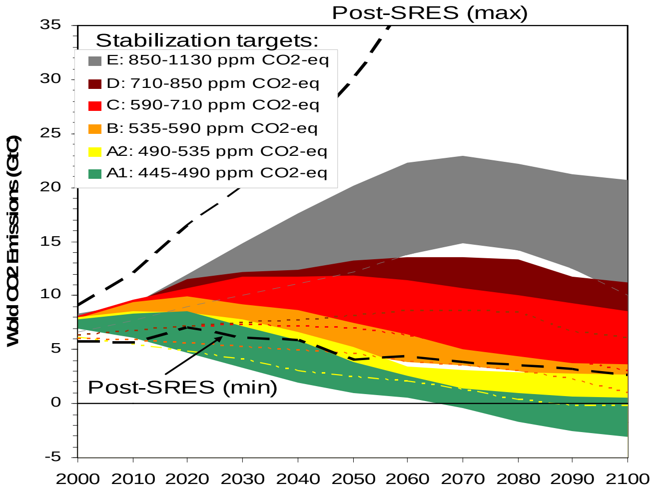
- The global economy has in recent years faced a number of changes and challenges.
- Globalization and free market economics have dominated the last decade, but the current financial crisis is rapidly changing the political landscape.
- The need to provide energy services with due respect to economic growth, sustainability and security of supply

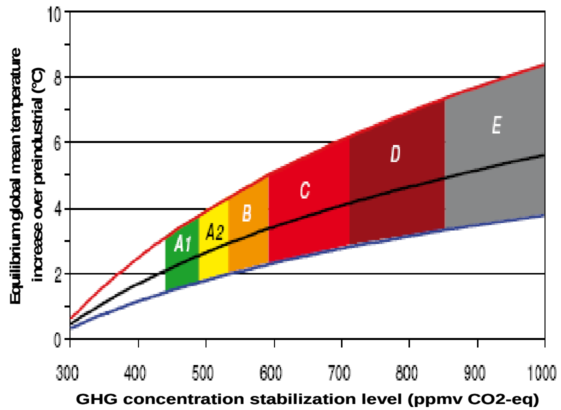
Climate change

- IPCC - 4. assessment report in 2007
- Nobel peace price
- COP15 in Copenhagen in December 2009

Climate Change:

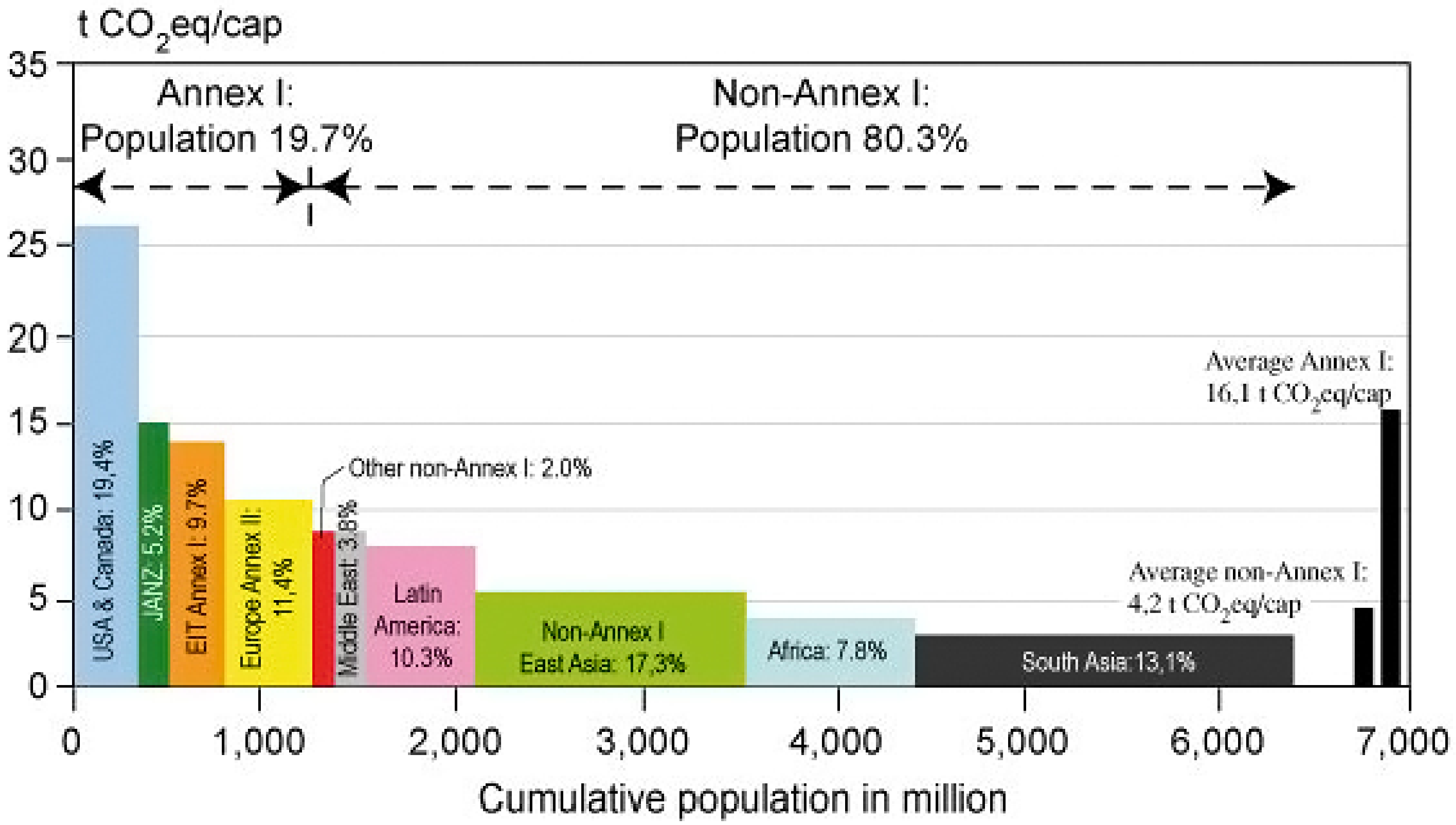
- The need to ensure a peak in CO_2 emissions before 2020 and at least a 50% reduction in the long run on a global scale e.g. in 2050 and later close to zero or even negative



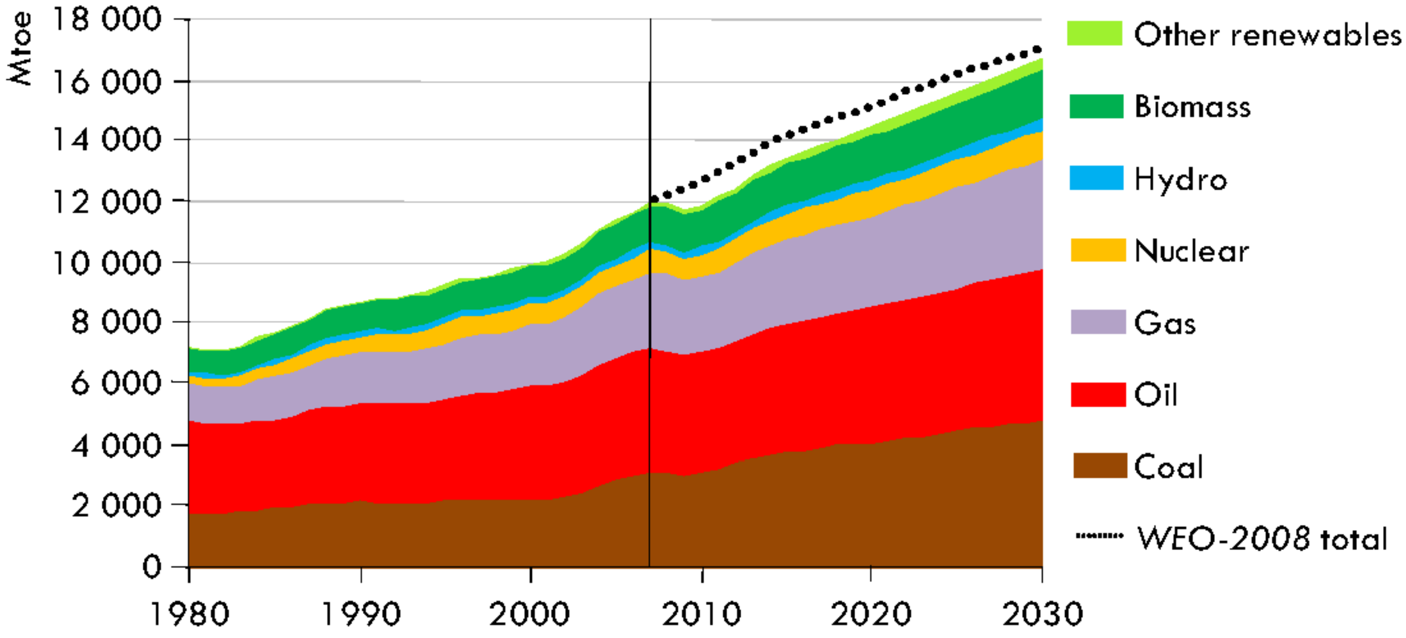


Source: IPCC 4 Assessment Report 2007

CO2 eq / cap   IPCC AR4

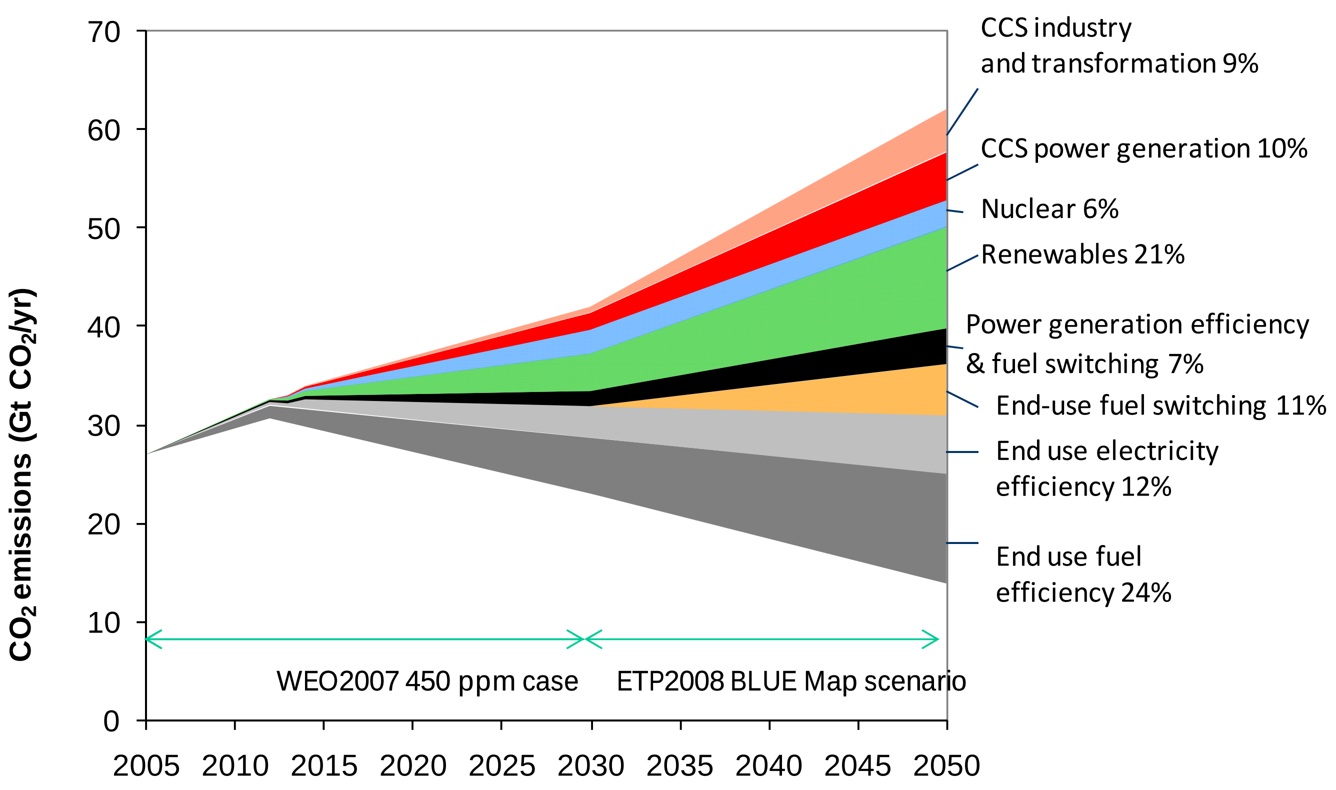


IEA World Energy Outlook 2009 , November 10



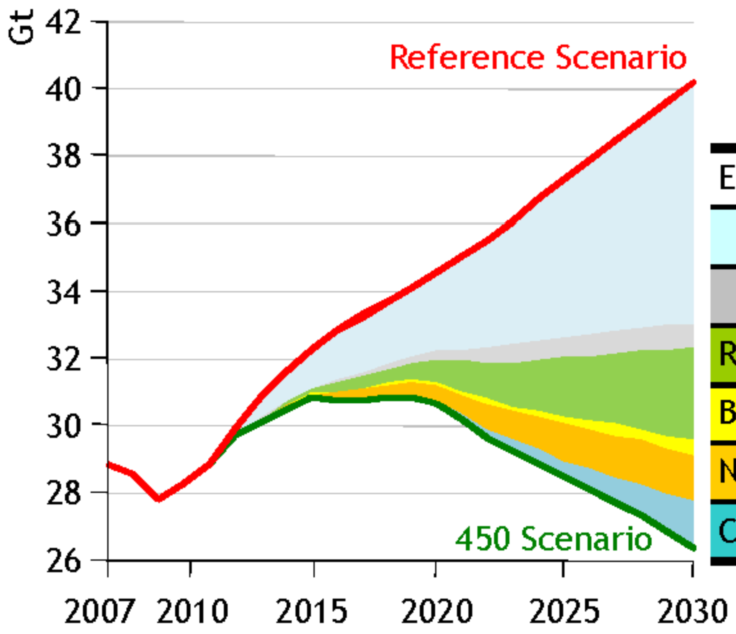
Global demand grows by 40% between 2007 and 2030, with coal use rising most in absolute terms

CO_2 emissions



Source: IEA

IEA World Energy Outlook 2009 , November 10

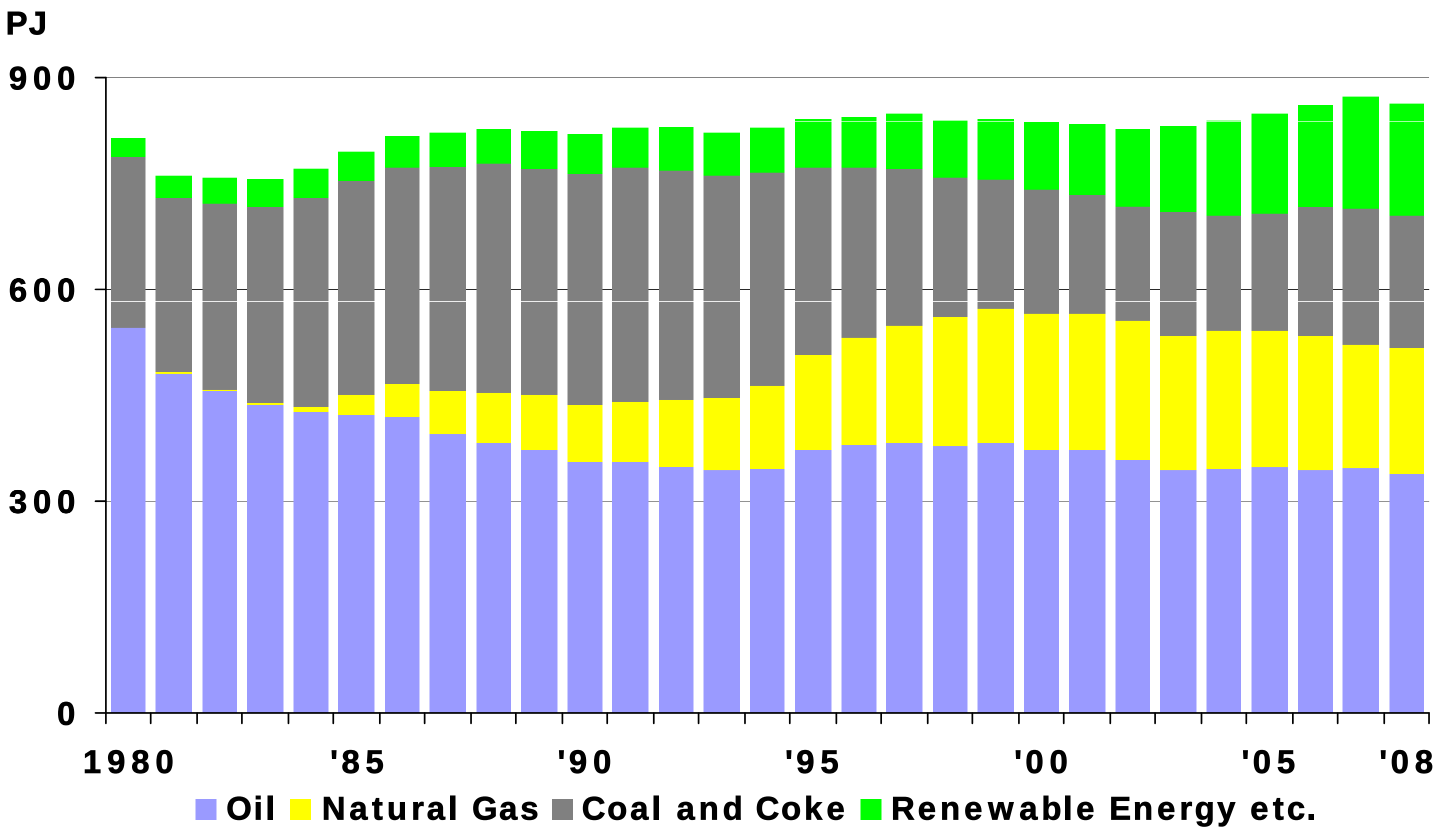


	Abatement (Mt CO_2)		Investment ($2008 billion)	
	2020	2030	2010-2020	2021-2030
Efficiency	2 517	7 880	1 999	5 586
End-use	*2 284*	*7 145*	*1 933*	*5 551*
Power plants	*233*	*735*	*66*	*35*
Renewables	680	2 741	527	2 260
Biofuels	57	429	27	378
Nuclear	493	1 380	125	491
CCS	102	1 410	56	646

Efficiency measures account for two-thirds of the 3.8 Gt of abatement in 2020, with renewables contributing close to one-fifth

Danish energy consumption has been stable over the last 25 years

- Is it possible to continue ...?

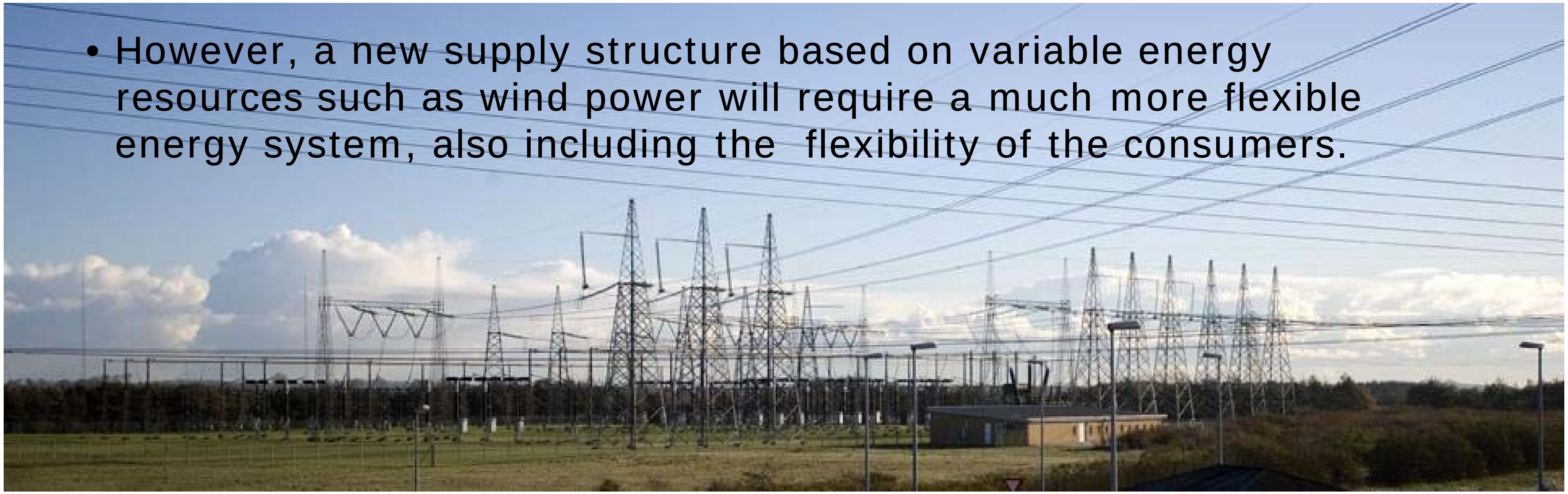


The energy system

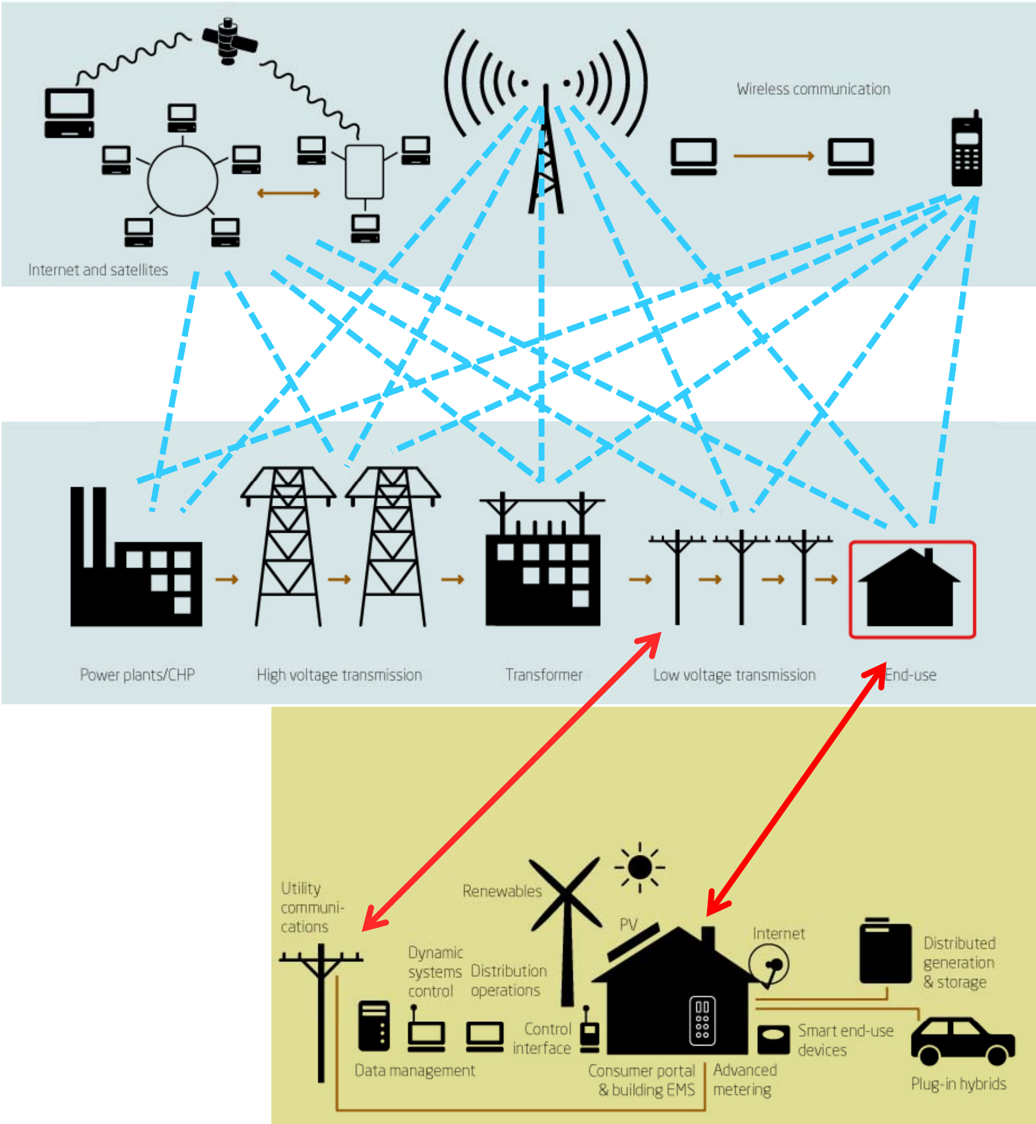
- Today’s energy system is the result of decisions taken over more than a century.

- This long-term development is reflected in the structure of the energy system, which in most cases was developed according to basic engineering requirements: energy is produced to meet the needs of consumers.

- However, a new supply structure based on variable energy resources such as wind power will require a much more flexible energy system, also including the flexibility of the consumers.



The future intelligent energy system



Information and Communication Technologies

+

Traditional power system structure

+

Distributed generation and efficient building and transport systems

=

The future intelligent energy system emerges

Structural changes in the power system

- The power system is currently undergoing fundamental structural changes.

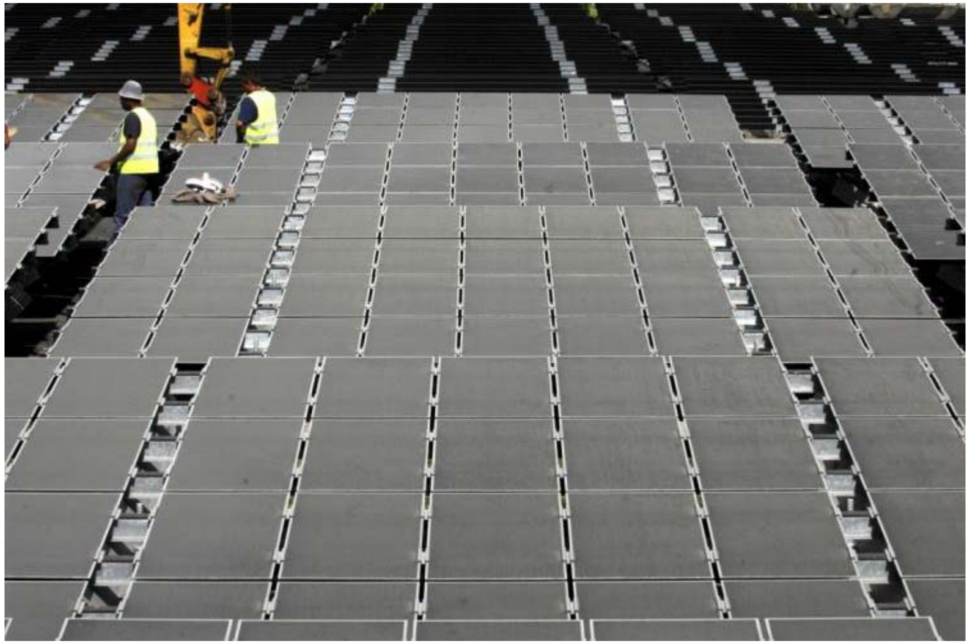
- The causes are:
  - – the rapidly increasing amount of fluctuating renewable energy
  - – the use of new types of production and end-use technologies.

Information and Communications Technology (ICT)

- Increased use of Information and Communications Technology (ICT)
- The rapidly increasing capabilities, and falling costs, of ICT open the way to two-way communication with end-users
- Making this one of the most important enabling technologies for the future power system.

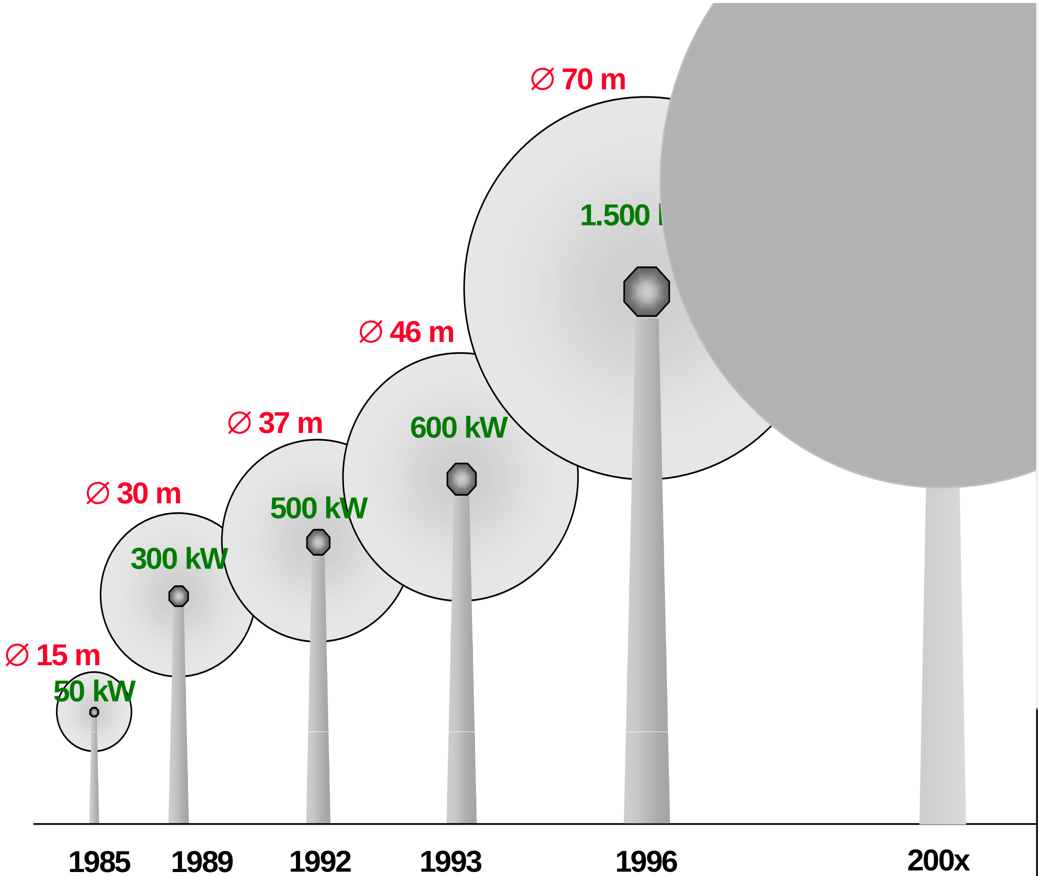
Renewable energy sources

- Renewable energy resources used to occupy an almost insignificant niche, are gradually expanding their role in global energy supply.
- Today the largest contributors are traditional biomass and hydropower
- “New renewables” such as photovoltaics, wind power, small-scale hydro, biogas and new biomass plays a minor role, but are expanding rapidly.

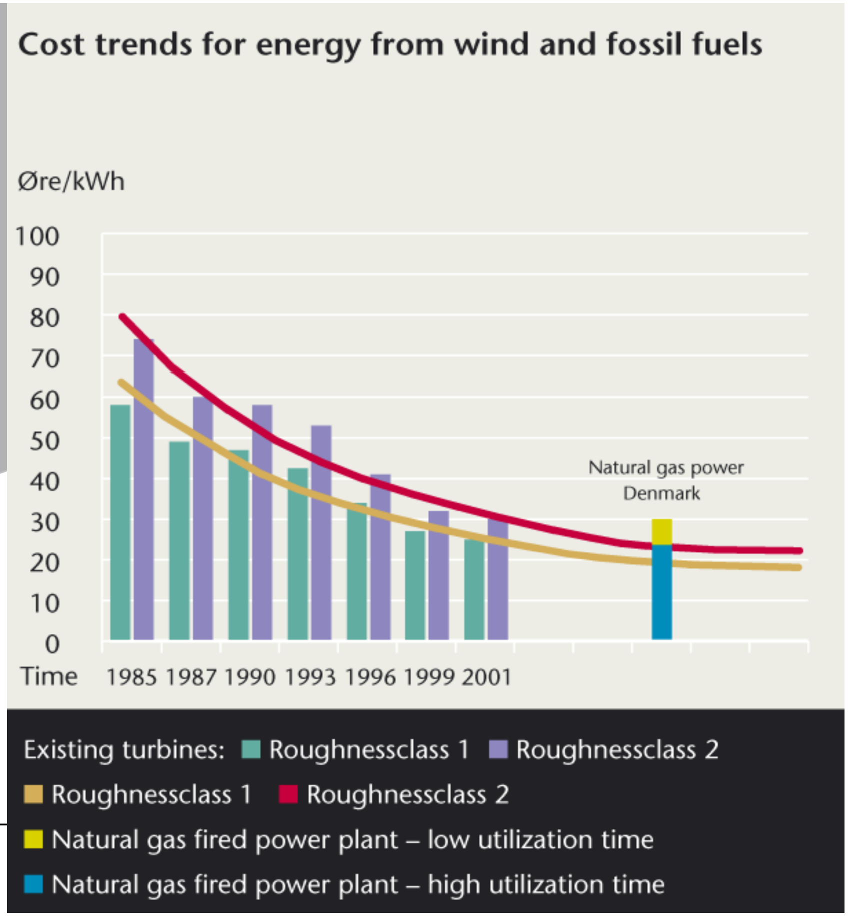


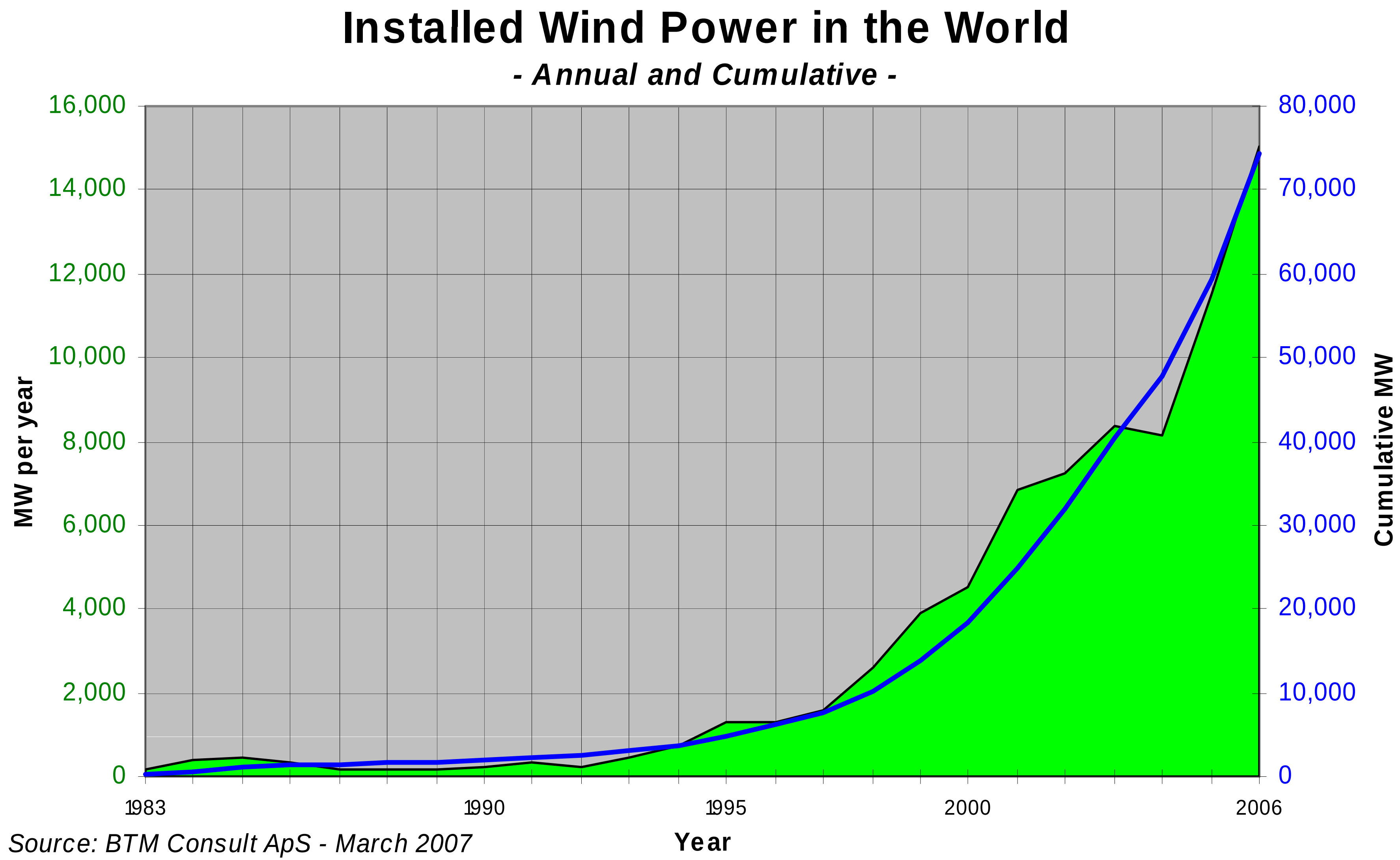
Wind energy

Development of wind turbines



Cost of energy from wind and fossil fuels




Installed Wind Power in the World
- Annual and Cumulative -
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
MW per year
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Cumulative MW
1983
1990
1995
2000
2006
Year
Source: BTM Consult ApS - March 2007

Technology for sustainable energy supply - Bioenergy

- Production and properties of biomass

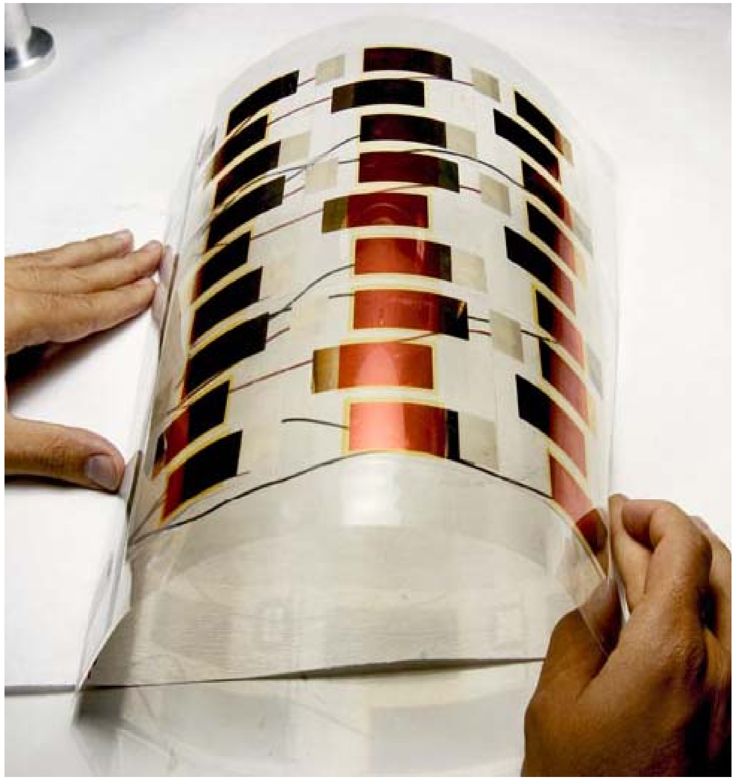
- Biomass conversion and co-production

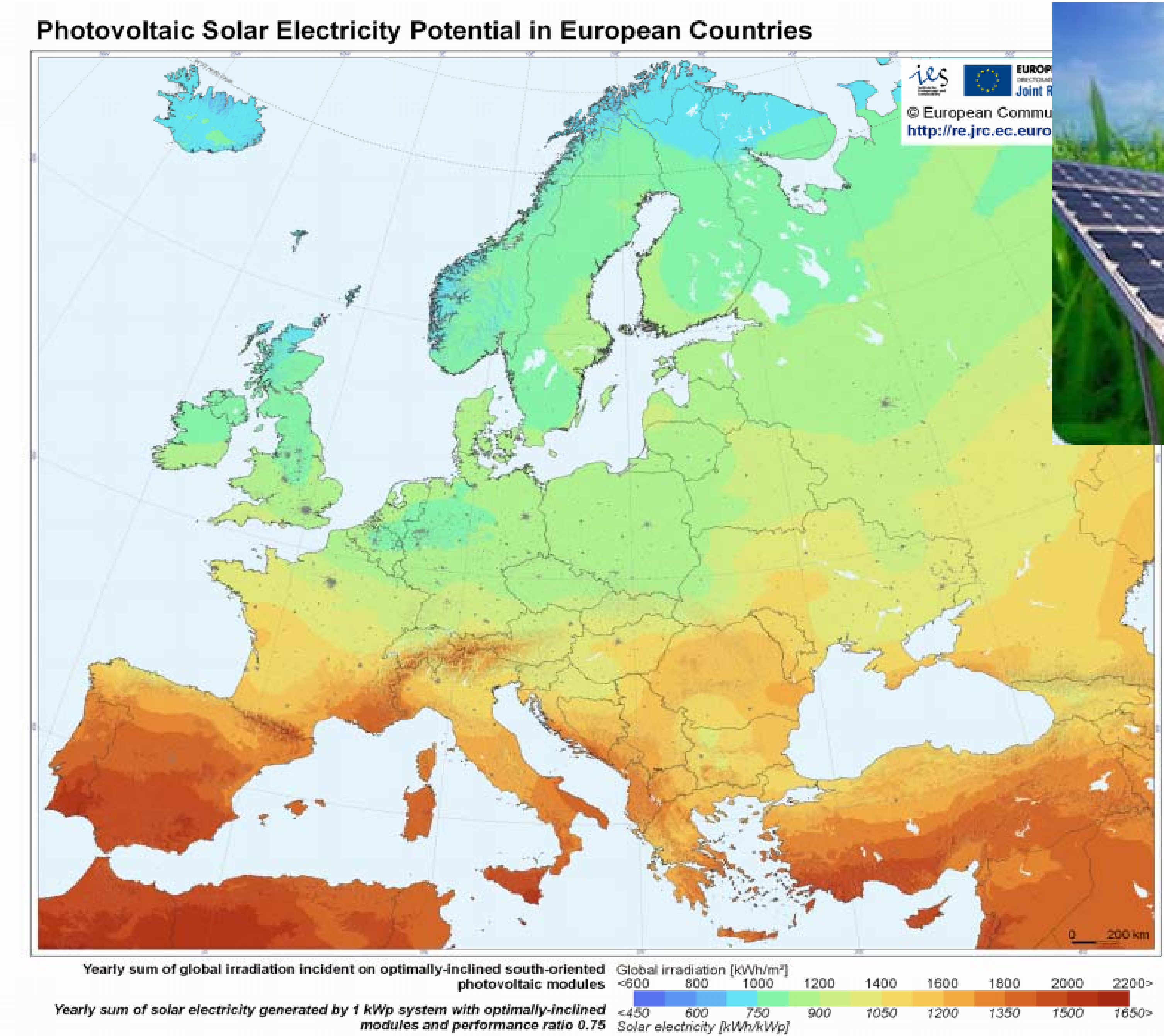
- The production of

  2 generation bio-fuel from straw by means of an internationally unique method

Photovoltaics

- The market for photovoltaic's has grown at an average of more than 30% annually over the last 10 years
- Crystalline silicon remains the standard PV technology with a market share above 90%
- Although efficiencies of solar cells continue to rise, high cost remains the principal barrier to PV as a large scale energy producers
- Polymer solar cells may succeed where silicon has failed because they are cheap to make

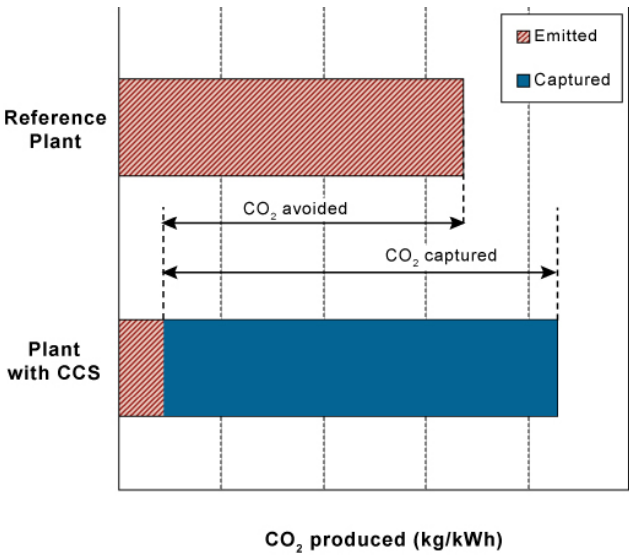


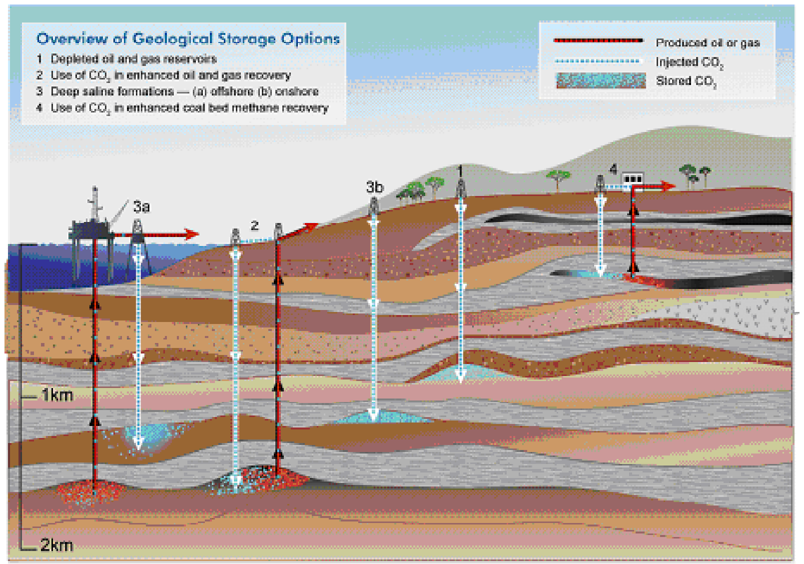


Different potentials in North and South

Carbon Capture and Storage - CCS

- Additional energy use of 10 - 40% (for same output)
- Capture efficiency: 85 - 95%
- Net CO_2 reduction: 80 - 90%
- Assuming safe storage





Storage

- Energy storage is needed in a future energy system dominated by fluctuating renewable energy depends on many factors:
  - the mix of energy sources,
  - the ability to shift demand,
  - the links between different energy vectors, and
  - the specific use of the energy.
- Storage costs and energy losses need to be considered.

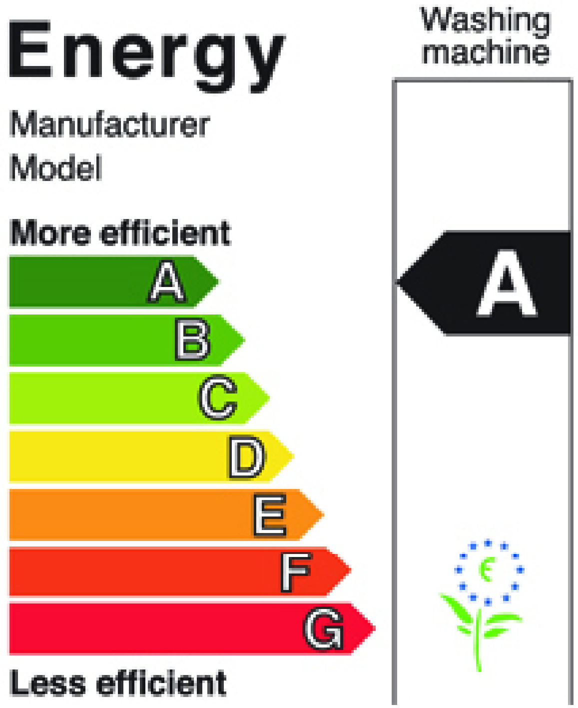
Transport sector

- Modern transport depends heavily on fossil fuels. Ways to reduce emissions from transport are to shift to renewable or at least CO_2-neutral energy sources, and to link the transport sector to the power system.

- Achieving this will require new fuels and traction technologies, and new ways to store energy in vehicles.

Efficiency improvements

- High emphasis on efficiency improvements in both industry and private households changing demand patterns are going to generate new challenges to system operators and utilities.



Self sufficient costumers

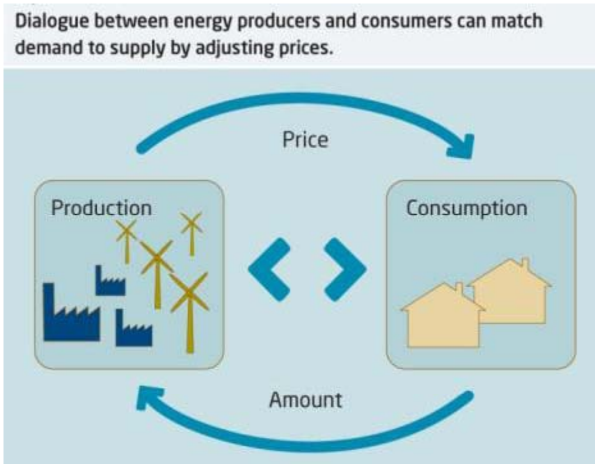
- The customers are becoming increasingly independent as they in long periods can be self-sufficient with energy by producing some of their limited need for electricity and heat by solar collectors, fuel cells etc.
- In short periods of time they are expecting the system to supply all their needs.

Volatile hourly prices

- A future electricity system with a considerable amount of fluctuating supply implies quite volatile hourly prices at the power exchange.

- Persuading customers to react to hourly prices would improve market efficiency, reduce price volatility, and increase welfare.

- Increasing the proportion of wind power in the system increases the benefits to consumers of acting flexible.



Flexible and intelligent energy system

Prerequisites:

- effectively accommodate large amounts of varying renewable energy;
- integrate the transport sector through the use of plug-in hybrids and electric vehicles;
- maximise the gains from a transition to intelligent, lowenergy buildings; and
- introduce advanced energy storage facilities in the system;
- Development of supergrids interconnection different regions

A high share of fluctuating energy sources

- Long-term targets for renewable energy deployment and stable energy policies are needed in order to reduce uncertainty for investors.
- A mix of distributed energy resources is needed to allow system balancing and provide flexibility in the electricity system.
- Electric vehicles, electric heating, heat pumps and small-scale distributed generation, such as fuel-cell-based microCHP, are promising options.

Long term development

- Apart from development of the future highly flexible and intelligent energy system infrastructure which facilitates substantial higher amounts of renewable energy than today's energy system
- there is also the need for development of new sustainable supply and end-use technologies for the period after 2050 where CO_2 emissions should be almost eliminated

Hydrogen and fuel cells

- Solid Oxide Fuel cells
- Electrolysis and other hydrogen technologies
- De-central and distributed energy system
- Enhances flexibility in the energy system

Why Hydrogen?

- Opportunity for a sustainable energy system
- Security of supply
- Climate change
- Alternative fuel for the transport sector
- New link between transport and other parts of the energy sector

Hydrogen is valuable today

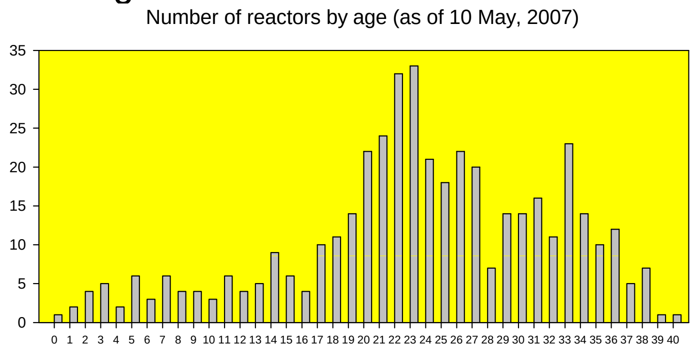
- Energy carrier – not energy source
- Manufactured on the basis of natural gas
- Utilized in refineries and chemical industry
- The hydrogen economy is technically feasible – the decisive factor is cost

Driving forces:

- Increased use of renewable energy in the transport sector
- Use in the transport sector can reduce local and global pollution
- The robustness and flexibility of the energy system will be increased

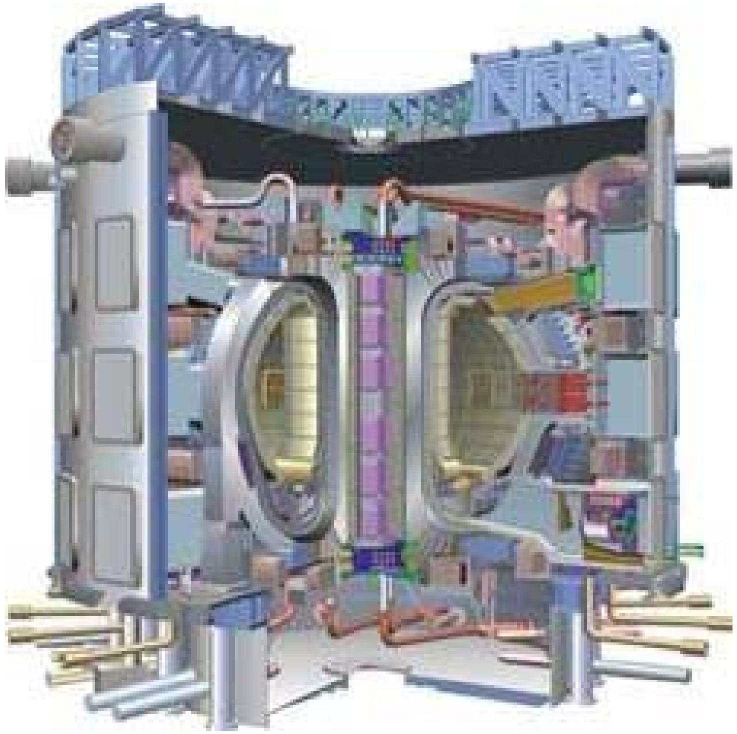
Nuclear Energy

- Nuclear fission energy provides 15% of the world electricity production. Globally, 440 reactors are in operation in 31 countries with most of the nuclear generation capacity being in Europe, in the US, and in Southeast Asia.
- Due to the high capital cost of nuclear reactors and low fuel prices nuclear energy is used predominantly for base load electricity production.
- The technology is fully developed and available to the market. However, the majority of existing nuclear power units was built in the 1970s and 1980s.
- Construction of nuclear power plants, however, continued in the Far East, especially in Japan and South Korea. Since 1990 the global installed capacity has increased only slightly to the present value of 370 GWe.
- Nuclear power is not vulnerable to even high fuel price fluctuations, and as it is based on uranium sources that are widely distributed around the globe.
- Most projections from IEA, IPCC and others expect some growths in the installed capacity of nuclear energy in the coming decades.



Fusion

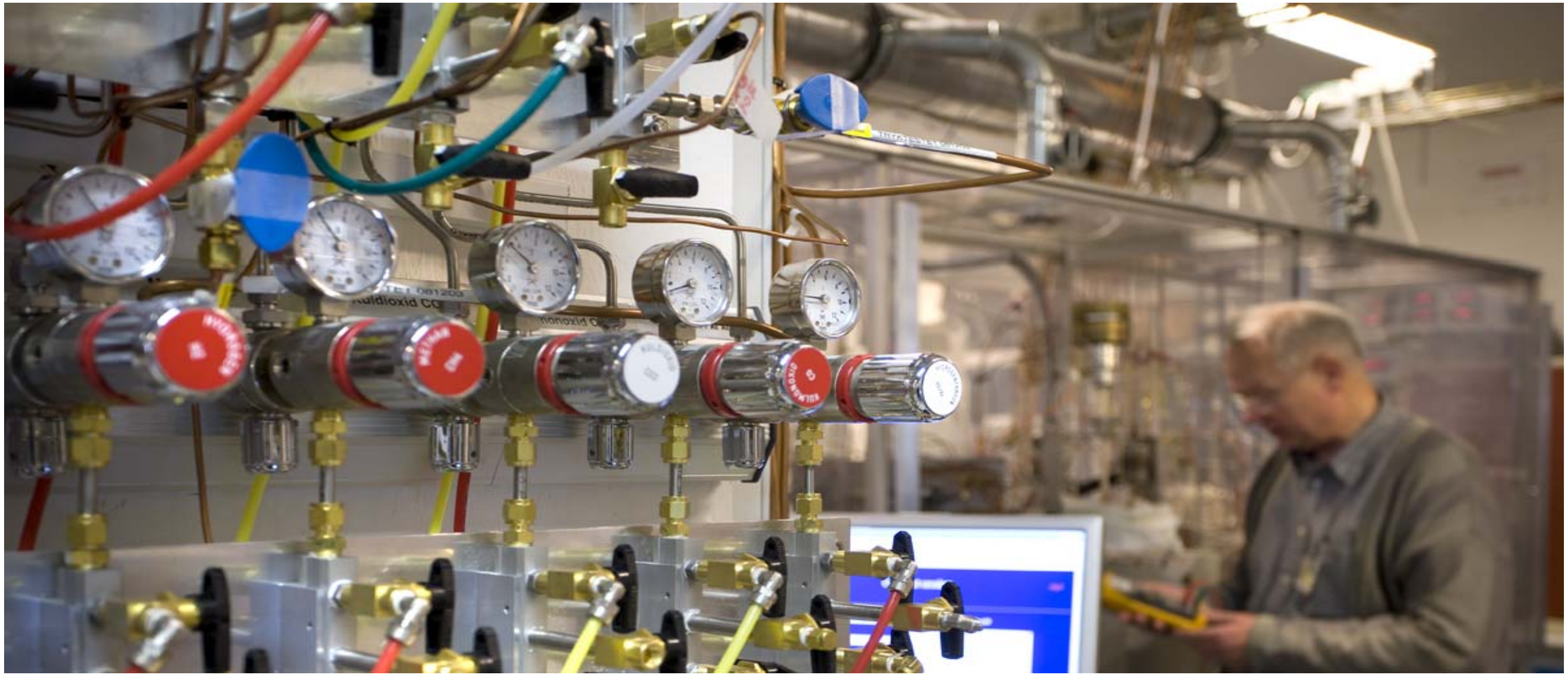
- Over the last five decades significant effort has been put in fusion energy research in most developed countries.
- The largest fusion experiment in the world is the Joint European Torus – JET – in Oxford, UK, started with the first plasma in 1983 and is still in operation.
- Europe is the host of the new international fusion experiment ITER.
- ITER is designed to generate 500 MW of fusion power, ten times more than the power needed to sustain the reaction. According to the present plan ITER will start operating in 2017.
- Maybe the first commercial fusion reactor in 2045



The ITER reactor

Long-term research

- Hence, there is a strong need to pursue long-term research and demonstration projects on new energy supply technologies, end-use technologies, and overall systems design. Existing research programmes in these areas should be redefined and coordinated so that they provide the best contribution to the goal of a future intelligent energy system.



Thank you for your attention